Geologic Resources
Vital Signs Monitoring Guidance

National Park Service
Geologic Resources Division
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Introduction

Geologic monitoring can be used to detect long term environmental change, provide insight into the ecological consequences of those changes, and to help determine if the observed changes dictate a change in park management practices. Monitoring of geologic resources can be used to assess whether environmental change is within a normal or anticipated range of variation. Geologic monitoring includes measurements of changes in volcanic activity, seismicity, glacier advance and retreat, shoreline movement, sand dune movement or mobilization, stream sediment storage and loading, thermal feature activity and temperature change, and slope and rock stability, among others.

Legal Mandates

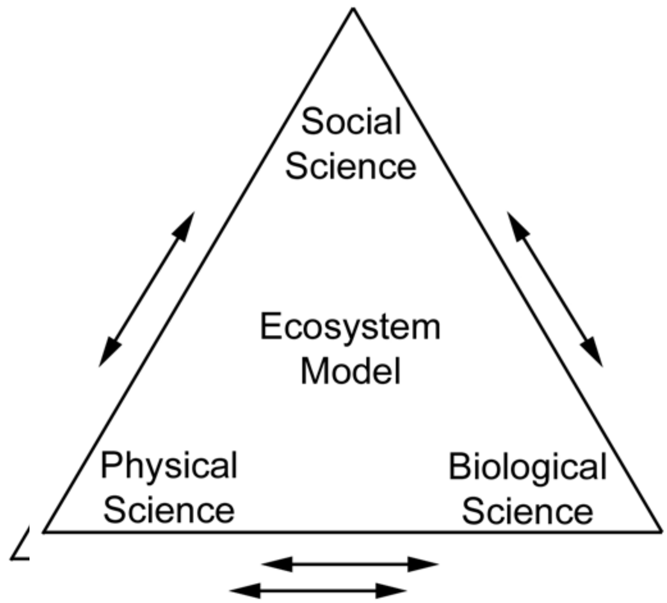
Monitoring of geologic resources can be linked to existing laws, regulations, executive orders, agency management strategies, and planning processes. The overarching statutes for monitoring natural resources in NPS units are the NPS Organic Act, the Government Performance and Results Act (GPRA), and the NPS Omnibus Management Act. Relevant resource-specific legislation includes; the Federal Cave Resources Protection Act (1988), Coastal Barrier Resource Protection Act (1982), Geothermal Steam Act (1970), Wild and Scenic Rivers Act (1968), Federal Water Pollution Control Act (formerly known as the Clean Water Act) (1972, as amended), Rivers and Harbors Act (1899, as amended), and the Coastal Zone Management Act (1972). Relevant Executive Orders include; 11988 – Floodplain Management (1977), 11990 – Wetland Protection (1977), 13189 – Coral Reef Protection (1998), and 13158 – Marine Protected Areas (2000).

In addition, park enabling legislation often addresses specific direction for the management of geologic resources. Over 160 parks have significant geologic resources and 83 parks exist because of a specific geologic theme identified in the park’s enabling legislation. NPS Management Policies (2001), Director’s Orders and initiatives (such as the Coral Reefs Initiative) can also provide guidance for monitoring geologic features and processes. Geologic monitoring should be addressed in a park’s General Management Plan (GMP), Resource Stewardship Plan (RSP) and possibly in the park’s Visitor Experience and Resource Protection Plan (VERP).

Monitoring of the Physical Components of an Ecosystem

It is unrealistic to attempt an evaluation of ecosystem function without considering the landscape and earth systems that act upon the landscape. Biological systems depend upon and interact with abiotic components. Without considering water, soil, rock, and atmospheric components, critical parts of the ecosystem would be overlooked. Physical systems can be early indicators of ecosystem change. Changes in physical systems can have significant impacts on human health and safety and human activities can, in turn, force changes in physical systems.

Effective resource management is based on understanding the ecosystem, not just one or several of its component parts. When developing an ecosystem study model for science-based management, it is important to consider the contributions of social, physical, and biological sciences. Monitoring the physical component provides important information on the complex interactions that take place within the ecosystem.



The physical component of the ecosystem is comprised of three basic parts, geology, hydrology and meteorology. Within these disciplines, changes in the ecosystem can be observed through measurements of the magnitudes, frequencies, rates, and trends of physical processes. Measurements that are particularly useful as indicators for detecting ecosystem change include processes occurring at or near the Earth's surface and those subject to change over periods of 100 years or less. The Commission on Geologic Sciences developed a list of "geoindicators" during a three-year international project for Environmental Planning (International Union of Geological Sciences). The Geologic Resources Division (GRD) has used the geoindicators concept as a basis for developing a list of geologic attributes (geo-attributes) that may warrant monitoring in NPS units. For a complete listing and description of the 27 geoindicators developed by the Commission on Geologic Science, see http://www.lgt.lt/geoin/. The following page includes a checklist of the geo-attributes and indicators identified by the GRD. Note that many of the indicators apply to several natural resource disciplines showing the close inter-relationship of biotic and abiotic resources within the ecosystem.

Table 1: List of geologic attributes and indicators for geologic monitoring.

GEOLOGIC ATTRIBUTE	Indicators	Importance for this Park	Natural Influence	Human Influence	Understanding Past Environments
Alpine and polar					
Glacial Features and Processes	Glaciers, glacial lakes, glacial dams, glacier movement (advance and retreat of glaciers), frozen ground activity, periglacial features, subsurface temperature regimes.		H	L - M	H
Arid and Semi-arid					
Windblown (Aeolian) Features and Processes	Dunes, loess deposits, desert surface crusts, wind and dust storm (magnitude, duration and frequency)		H	M - H	M
Coastal and Marine					
Marine Features and Processes (submerged resources)	Reefs, channels, sandbars, shoals, hardbottom, sand waves, tidal deltas, submerged abiotic resources, coral chemistry, sedimentation, benthic habitat		H	H	H
Coastal Features and Processes	Beaches, bluffs, dunes, rocky coasts, maritime forests, barrier islands, salt marshes, tides pools, estuaries, bays, inlets, shoreline position, relative sealevel, shoreline composition, sediment sequence and composition		H	M - H	H
Groundwater-related					
Caves and Karst Features and Processes	Caves (karst and nonkarst), karst landscapes and systems, sedimentation processes, water quality and chemistry		H	M	H
Geothermal Features and Processes	Hot springs, geysers, fumaroles, mineral precipitates and formations, mudpots, hydrophytic biotic communities, water quality, and chemistry				
Surface water-related					
Lake (Lacustrine) Features and Processes	Lakes, sedimentation, water levels, sediment sequence and composition, stability of lake outlet, water quality, glacial lakes, and lake clarity		H	H	M

GEOLOGIC ATTRIBUTE	Indicators	Importance for this Park	Natural Influence	Human Influence	Understanding Past Environments
Stream (Fluvial) Features and Processes	Stream channel shape, morphology, substrate, stream flow, stream sediment storage and load, and sediment regime (timing, duration, and pattern of flows)		H	H	L - M
Hazards					
Volcanic Features and Processes	Volcanoes, lava tubes, vents, lava flows, pyroclastic flows, lahars, tephra, volcanic gases		H	L	H
Seismicity	Surface displacement, tsunamis		H	M	L
Hillslope Features and Processes	Landslides, rockfalls, avalanches, creep, seismicity, snow avalanches		H	H	M
Fossilized Biologic Remains					
Paleontologic Resources			H	H	H

H - HIGHLY influenced by, or with important utility for
M - MODERATELY influenced by, or have some utility for
L - LOW or no substantial influence on, or utility for

Geo-Attributes Overview

Geologic attributes have been identified to assist NPS staff in the integrated assessment of natural ecosystem health. In consultation with geologic specialists, vital signs monitoring networks can use the geo-attribute checklist to identify which geologic resources should be included in its overall monitoring program. The preliminary identification of geo-attributes to include in the vital signs monitoring program should be accomplished during the network's Phase 1 Conceptual Modeling workshop. Networks and parks may also request the GRD to conduct a Geologic Resources Evaluation scoping meeting to discuss a park's geologic features and processes, mapping needs, and possible geo-attributes that warrant monitoring. The following description of the significance of each geo-attribute may prove helpful when selecting which geologic resources should be monitored in a given park or network:

Glacial Features and Processes: Glaciers are highly sensitive, natural, large-scale indicators of hydrologic and energy balance in polar regions and at high elevations of the Earth's surface. A glacier's capacity to store water for extended periods of time exerts a significant control on the surface water cycle, and its presence exerts a powerful influence on nearby physical and biological processes. The advance and retreat of glaciers creates hazards to nearby human structures and communities through avalanches, slope failure, and catastrophic outburst floods from lakes beneath glaciers and those dammed by ice and glacial moraines.

Glaciers grow or diminish in response to natural climatic fluctuations. The size and volume of mountain glaciers has decreased throughout the world over the past 150 years, providing strong evidence of global warming and decreasing precipitation. Glaciers buffer ecosystems from extreme low flow periods, affecting baseflows and the timing and amount of runoff.

Windblown (Aeolian) Features and Processes: Aeolian processes are a natural phenomenon, but their affects may be exacerbated by human actions such as cultivation, overgrazing, water use, and urbanization. Changes in dune morphology or position may indicate variations in climate, wind velocity and direction, or disturbance by humans. Changes in wind-shaped surface morphology and vegetation related to desertification, drought, aridification, and wet cycles (fire can also affect vegetation cover) are important gauges of environmental change in arid and semi-arid regions. Sand that has become stabilized by vegetation can become mobilized and greatly change the nature of the landscape and ecosystem.

Dust storm frequency, duration, and magnitude may be indicative of climate change and changes in wind speed and direction. Dust storms are natural events, but the amount of sediment available for transport may be related to surface disturbances such as overgrazing, plowing, vegetation removal, fire, and urbanization. Dust in the atmosphere can influence weather patterns and can be a human health concern. Airborne deposition of particles is also a concern for many parks because it can result in changes in soil, sediment, and water chemistry, modify vegetation communities, and diminish visibility. The loss or encroachment of vegetation on sand deposits greatly affects dune's stability and ecosystem diversity.

Coastal Features and Processes: Erosion and accretion of shoreline deposits and relative shoreline position are important factors in determining ecosystem health and appropriate land uses in coastal areas. Human activities such as dredging, beach mining, river modifications, installation of coastal barriers (breakwaters, groins, jetties, etc.), removal of vegetation, and reclamation of nearshore areas as well as short-term storm events can significantly affect shoreline processes, shoreline position, and morphology. Changes in relative sea level may alter the position and morphology of coastlines, causing coastal flooding, saturation of soils, and a gain or loss of land. Changes in the shoreline position may also create or destroy coastal wetlands and salt marshes, inundate coastal settlements, affect coastal structures, and communities, and induce saltwater intrusion into aquifers, resulting in groundwater salinization.

Subtle changes in sediment supply, physical processes, and anthropogenic impacts can shift the balance between shoreline stability, accretion, or erosion. Beach nourishment and dredging, construction of jetties and seawalls, and armoring coastlines are examples of anthropogenic shoreline modifications. Shoreline changes may have significant implications for coastal ecosystems, human settlements, and coastal land uses. Relative sea level variations may be natural responses to climate change, geoidal variations, movements of the seafloor, other earth processes, and responses to human actions including draining wetlands, and groundwater withdrawal.

Marine Features and Processes (submerged resources): Marine ecosystems are not as well understood and documented as most terrestrial ecosystems. Physical processes drive the dynamics of the marine environment from larval recruitment to exchange of estuarine waters over a tidal cycle. Anthropogenic and climate change induced modifications of our coastal lands and waters directly impact the marine environment The health, diversity and extent of corals, and the geochemical make-up of their skeletons, record a variety of changes in marine waters. These include temperature, salinity, fertility, insolation, precipitation, winds, sea level rise and fall, storm incidence, river run-off, and human inputs. Corals in coastal areas are susceptible to rapid changes in salinity and suspended matter concentrations and may be valuable indicators of the marine dispersion of agricultural, urban, mining, and industrial pollutants through river systems, as well as the history of contamination from coastal areas.

Changes in sediment supply, physical processes, and anthropogenic impacts can alter the health of coral reef ecosystems or fish habitat. Relative sea level variations may permanently expose marine habitat to terrestrial forces or submerge additional lands. Altered nearshore currents and transport pathways may impact the success of larval recruitment, cause increased rates of shoreline erosion, and adversely impact water quality.

Caves and Karst Features and Processes: Karst is a type of landscape found in carbonate rocks (limestone, dolomite, marble) or evaporites (gypsum, anhydrite, rock salt) and is typified by a wide range of closed surface depressions, a well-developed underground drainage system, and a paucity of surface streams. The highly varied interactions among chemical, physical and biological processes result in a broad range of geological effects including dissolution, precipitation, sedimentation, and ground subsidence. Diagnostic features such as sinkholes, sinking streams, caves, and large springs are the result of the solutional action of circulating groundwater. Caves contain a variety of dissolution features, sediments and speleothems (deposits with various forms and mineralogy, chiefly calcite), all of which may preserve a record of the human, paleontological, geological, and climatic history of the area and provide habitat for a variety of life forms including microorganisms living in extreme environments. Caves also form in non-karst environments and can include sea or littoral caves, tectonic fractures and lava tubes.

Cave and karst systems are sensitive to many environmental factors. The construction of poorly designed structures in caves such as expanded entrances, elevator shafts, and gates have led to the destruction of cave resources through the interference with air flow patterns and animal movement. For example, a "bat-unfriendly" cave gate inhibits the daily passage of bats into and out of a cave, often resulting in the abandonment of the cave by the bats altogether. Because of reduction in available habitat, over 50% of the bat species in the United States are in significant decline or are endangered.

Urbanization is creeping up on parks including those with cave resources. Water, which is the building force of most caves, carves cave passages and sculpts unique speleothems by dripping and seeping year after year in exactly the same way. Cave species organize their existence around these water sources and depend upon them for their survival. Increased human activity, including NPS activity, such as agriculture and road network expansion threatens the quality and the quantity of the water that feeds and sustains cave systems.

Unregulated or illegal access to caves in some cases has resulted in the destruction of cave resources. Vandals may steal or deface unique cave formations and archaeological specimens. In addition, recreational visitors inadvertently import exotic species (e.g., spores, fungi), which affects the integrity of the biotic web,

Geothermal Features and Processes: Geothermal features are a reflection of thermal processes that occur beneath the Earth's surface, often at great depth. The Geothermal Steam Act Amendments of 1988 (P. L. 100-443) require that the National Park Service establish and maintain a monitoring program for all units of the National Park System which have thermal features qualifying as "significant" (sixteen NPS units were identified in the Act). The Act requires the NPS to establish a research and monitoring program to collect and assess data for geothermal features.

There is a risk that surface geothermal features (e.g., hot springs, mineral pools, geysers) may be altered or permanently lost due to geothermal development in and around parks. The impacts of geothermal resource development on volcanic (non-hydrothermal) features are not well understood, and care must be taken to prevent irreversible impacts on these as well.

Geothermal processes can also create, perpetuate, or impact existing surface features and environments where the waters are discharged onto the surface. In addition, geothermal systems are often sites of intensive biological activity (bacteria, viruses, fungi, and protozoa).

Lake (Lacustrine) Features and Processes: Lakes are dynamic systems that are sensitive to climate change and adjacent land uses. Lake level fluctuations and analysis of isotopes, fossil pollen, spores, and seeds in lake sediments can provide a detailed historic record of climate and vegetation change. Lake sediments preserve a record of past or ongoing environmental processes and components, both natural and human induced, including soil erosion, mass wasting, and the composition of air-transported particulates and contaminants from a variety of land uses. Lakes can also be a valuable indicator of near surface groundwater conditions.

Sediment deposition is a natural process that can be strongly influenced by human activities (e.g., land clearing, agriculture, deforestation, acidification, eutrophication, industrial pollution, fire, and diseases) within a watershed. Lake sediments preserve the chemical, physical, and biological composition in a chronologically ordered and resolvable record of physical and chemical changes through their mineralogy, structure, and geochemistry. Studying sediment sequences is important in order to understand the types, magnitude, and significance of environmental change in a watershed. Monitoring changes in sediment volumes can be used to understand changes in lake nutrients and biota.

Stream (Fluvial) Features and Processes: Rivers are dynamic systems that are subject to rapid changes in channel shape and pattern, streamflow, sediment transport, and sediment storage. Changes in stream processes can indicate changes in land-use or watershed conditions. An understanding of stream morphology, discharge, stream sediment storage, and load can help document channel response to human induced environmental changes such as agricultural practices, mining, dredging, logging, roads, and urbanization. For example, changes in sediment yield can reflect changes in basin conditions, including soil quality, erosion rates, vegetative cover, and hillslope stability. Watershed disturbances such as floods, fire, and land uses can significantly alter the sediment supply to streams. Armoring of streambanks with riprap or retaining walls can significantly affect riparian biota. Fluctuations in sediment discharge can affect both biotic and abiotic ecosystem processes. Nutrients are transported with the sediment load. Higher suspended sediment loads and turbidity directly affect aquatic organisms and variable sediment transport rates can impact the quality of stream habitat and riparian systems.

Stream processes play a key role in regulating and maintaining biodiversity. The physical component of a functioning aquatic ecosystem includes complex habitats and consists of floodplains, streambanks, channel structure, and flowing water. These features are created and maintained by stream channel processes and are influenced by watershed condition and health. The physical, hydraulic, and chemical properties of streams and rivers determine their suitability as habitat for aquatic species (fish, wildlife, amphibians and macroinvertebrates) and can also affect riparian vegetation and habitats. For example, fluctuations in sediment load directly affect stream habitat. Salmon and steelhead require clean gravels for spawning and egg survival, juveniles need complex stream habitat (pools and riffles), good water quality and cover for protection from predators provided by overhanging vegetation, undercut banks, submerged logs, and rocks. Long-term monitoring of basic stream attributes can be used to document trends in stream channel conditions, channel response to large disturbance events, and be used to measure ecosystem recovery.

Volcanic Features and Processes: Volcanism is a natural phenomenon that is not heavily influenced by human actions. In rare instances barriers and water have been used to slow or divert the flow of lava away from human structures. The effects of volcanic eruptions are a primary concern for human health and safety and potential damage to natural and cultural resources and human developments. Natural hazards associated with eruptions of active volcanoes pose a threat to approximately 10% of the world's population.

Volcanic eruptions can have profound effects on the environment through heat, impact, deposition, and gas chemistry, on scales ranging from local to regional. Significant topographic and fluvial changes may occur following a volcanic eruption, and surface ecosystems may be sterilized, creating new, very different habitats. The U.S. Geological Survey monitors volcanic activity in many units of the National Park System.

Seismicity: Displacement of the Earth's surface results from active tectonic processes within the Earth, collapse into underground cavities, or the compaction of surficial materials. Sudden movements may be caused by faulting associated with earthquakes, and from the collapse of rock or sediment into natural holes in soluble rocks (e.g. salt, gypsum, limestone, or into cavities produced by mining of near-surface rocks (especially coal) and solution-mining of salt. Slower local subsidence may also be induced by: fluid withdrawal (gas, oil, groundwater, geothermal fluids); densification or loss of mass in peat being developed for agriculture; drainage of surface waters from wetlands, which can cause oxidation, erosion and compaction of unconsolidated soils and sediments; and filtration of surface water through porous sediments such as loess. On a much larger scale, the land surface elevation responds slowly to plate movements, compaction of sedimentary basins, and glacial rebound.

Shallow-focus earthquakes (those with sources within a few tens of kilometers of the Earth's surface) are caused by crustal movements along strike-slip, normal and thrust faults, though they can also be induced anthropogenically. They can result in marked temporary or permanent changes in the landscape, depending on the magnitude of the earthquake, the location of its epicenter, and local soil and rock conditions. Deep-focus earthquakes (below about 70 kilometers) unless of the highest magnitude, are unlikely to have serious surface manifestations.

Earthquakes constitute one of the greatest natural hazards to human society. Surface effects include uplift or subsidence, surface faulting, landslides and debris flows, liquefaction, ground shaking, and tsunamis (a series of 'tidal' waves caused by undersea tremors). Damage to buildings, roads, sewers, gas and water lines, power and telephone systems, and other built structures commonly occurs from seismic events and if they occur, tsunamis. To avoid, reduce or warn of environmental impacts, it is necessary to know the size, location, and frequency of seismic events, and the historic record of tsunamis. The spatial pattern of seismicity, including the presence of seismic gaps, and the relationship to known faults and active volcanoes is also important in predicting future seismic events.

Hillslope Features and Processes: Measurement of hillslope processes over time can give an indication of environmental stresses (deforestation, road building, and weather extremes) and provide important insights into landscape and ecosystem changes. Geologic features created by hillslope processes can be caused by natural processes (erosion, freeze–thaw cycles, climate change, faulting) and / or human actions (construction of roads and structures, agricultural practices, logging, quarrying, vibrations, drainage from pipes, culverts, mining etc.).

Mass movement of rock, debris and sediment may take place suddenly (debris and snow avalanches, lahars, rock falls and slides, debris flows) or more slowly (slumping, creep, solifluction). Human activities can accelerate or slow the natural rate of hillslope processes, wildfires can promote mass movements by destroying vegetative cover, and climate change can indirectly affect the rate and magnitude of hillslope processes. Hillslope processes can alter habitat, impact downslope resources, and add sediment to waterways.

Paleontologic Resources: Paleontology is the study of ancient life and encompasses all of the kingdoms of life, although not all of the currently recognized kingdoms are preserved in the fossil record. Fossils – the preserved remains of life found in the rock record – are divided into body and trace fossils, body fossils are the direct evidence of the actual physical remains of past life and trace fossils are indications of activity and include tracks, burrows, gnaw marks and coprolites. The chances for preservation of a body fossil are greater if there are hard parts such as skeleton or a shell but under special circumstances soft tissues may be preserved. There are many ways a plant or animal may be preserved as fossil depending on the circumstances of their burial. The different types of preservation may provide important clues about the circumstances under which they lived or died.

Studying paleontology can help us understand past ecosystems and current and future changes to ecosystems. Fossils are the only direct evidence about the history of life on our planet. The geological context in which a fossil is found is often as important as the fossil itself if a paleontologist is to understand the history of life and how it has responded to environmental changes. The science of paleontology has many sub-disciplines depending on the type of organism and may look at relationships between different groups of organisms, how they evolved, ancient ecosystems, adaptations and the origins and extinctions of groups. In some cases paleontology is closely tied to economic aspects of geology such as increasing our knowledge about coal and oil and how they are formed.

In order to minimize adverse impacts to paleontological resources it is important to inventory the geologic formations that may contain fossils, and to protect these areas during ground disturbing activities in the park. Knowledge of fossil collecting sites adjacent to the park may help park staff identify potential fossil bearing formations inside the park. Once the paleontological sites are identified it is important to monitor the sites using standard monitoring protocols to ensure their long term protection.

Geologic Monitoring

Geologic monitoring involves collecting information through observing, measuring and sampling elements of geologic processes and their resulting geologic features. This can be done on the ground or remotely, either by an individual or a team. Some monitoring is very complex and requires sophisticated instruments operated by scientists and trained technicians; while other types of geologic monitoring utilizes standard measuring and recording devices that can be used with minimal training.

When parks consider vital indicators, it is important to be familiar with the possible monitoring activities and any potential for damage to park resources. Activities associated with geologic monitoring include using GPS, aerial photography, repeat photography, seismography, temperature readings, remote sensing, surveying, measuring flow rates, gathering meteorology data, and others. Monitoring of geologic resources can easily be conducted in a resource-sensitive and park friendly manner.

In some cases scientists and highly trained technicians will be needed to do the geologic monitoring but often other park staff or non-park personnel such as students, retirees, or volunteer participants can carry out routine measurements or observations. Park personnel should always be "active" members of the monitoring team. Park involvement/oversight will ensure that the monitoring protocols are being followed, NPS stays connected to the monitoring project, park needs continue to be addressed, management is kept informed, and information transfer extends throughout the NPS network. Because park staff is located on-site they will probably be most effective in implementing field activities and recording the data in park databases, such as, GIS and Synthesis.

Recommendations for the Design of Geologic Resources Monitoring Programs in the NPS Vital Signs Monitoring Networks

This section outlines the recommend steps each monitoring network should follow to ensure adequate planning for the monitoring of geologic resources. Although a few monitoring networks may have already addressed some of these steps, the following outline should help all networks to ensure a comprehensive review of their geologic monitoring needs.

A. Identify geologic expertise:

1. Most networks do not have geologic expertise and will need to develop a team of specialists to consult with them for evaluation and design of geologic monitoring. The Geologic Resources Division is available to all networks to help locate geoscientists for this purpose - Contact Lisa Norby, GRD Monitoring Coordinator for assistance, at lisa_norby@nps.gov, or call (303) 969-2318.

2. Geologic expertise will be identified from the following geologic community:

    a) GRD geology staff and other NPS geologists,
    b) U.S. Geological Survey,
    c) American Association of State Geologists,
    d) Geological and Paleontological societies (GSA, AGU, AWG, AGI, AIPG, NABGG, NSS etc.)
    e) Local geological organizations,
    f) University partners, and
    g) Museum geologists.

3. Networks should recruit geoscientists to participate in workshops, review proposed monitoring strategies and design monitoring protocols.

B. Have geoscience expert(s) compile a summary of existing park-specific geologic monitoring and information sources for the network.

C. Discuss park-specific geologic monitoring needs with the identified geologic experts, and GRD and park staff during Geologic Resource Evaluation (inventory) scoping meetings.

D. Have geoscientists participate in network workshops to:

1. Rate the selected geo-attributes and determine which ones are significant for monitoring in parks within the network;

2. Compile a description of alternatives (methods) for comprehensive monitoring of all priority geo-attributes, including any potential for using existing monitoring done by other organizations;

3. Identify opportunities to monitor multiple resources using a single technology; (An example would be aerial photography along a shoreline that monitors shoreline movement and also records changes in vegetation.)

4. Work with network resource specialists to identify preferred options for implementing geologic monitoring in parks (cost effective, resource friendly, easy to measure and duplicate for time series analysis with adequate accuracy and precision);

5. Write a geology panel report for the network (based on network format or outline below);

Introduction
Summary of group discussion
Results - for each vital sign chosen, report the following:

- Management Issue:
- Monitoring Question Addressed:
- Vital Sign:
- What ecosystems does this Vital Sign apply to?
- Why was this vital sign chosen?
- Other information (monitoring information, protocols, costs, potential partners, related on-going research, suggested inventory needs, reviewers, etc.):
- Contact person:
- Methods
- Design and Implementation

6. Recommend specialists to design specific monitoring protocols (in some instances, panel members can do this at the workshop).

Since networks were designed primarily along the boundaries of Bailey's Ecoregions, many parks in a network will have similar monitoring needs and priorities. However, in a number of cases individual parks will have unique ecosystems with specific monitoring needs. Allowances should be made for this, and specialized geologic expertise should be made available to help these parks. This could be done through "break-out" sessions at the main network meeting, separate meetings on-site, or perhaps through conference calls. An example of geologic features that may be unique to one or several parks in a network include parks with caves, volcanoes, and shorelines.

E. Continuing Geologic Monitoring Process

1. Networks will need to incorporate geologic resource monitoring into their ecosystem monitoring program.

2. The NPS Geologic Resource Division is available to parks and networks to implement monitoring strategies, facilitate partnerships, and reevaluate monitoring protocols as the program evolves.

3. In many cases, the geoscientists that participate in network workshops will be willing to assist with developing partnership agreements to collect, process, and analyze monitoring data.